

Next Generation HVAC Systems Smarter, Smaller, and more Adaptive

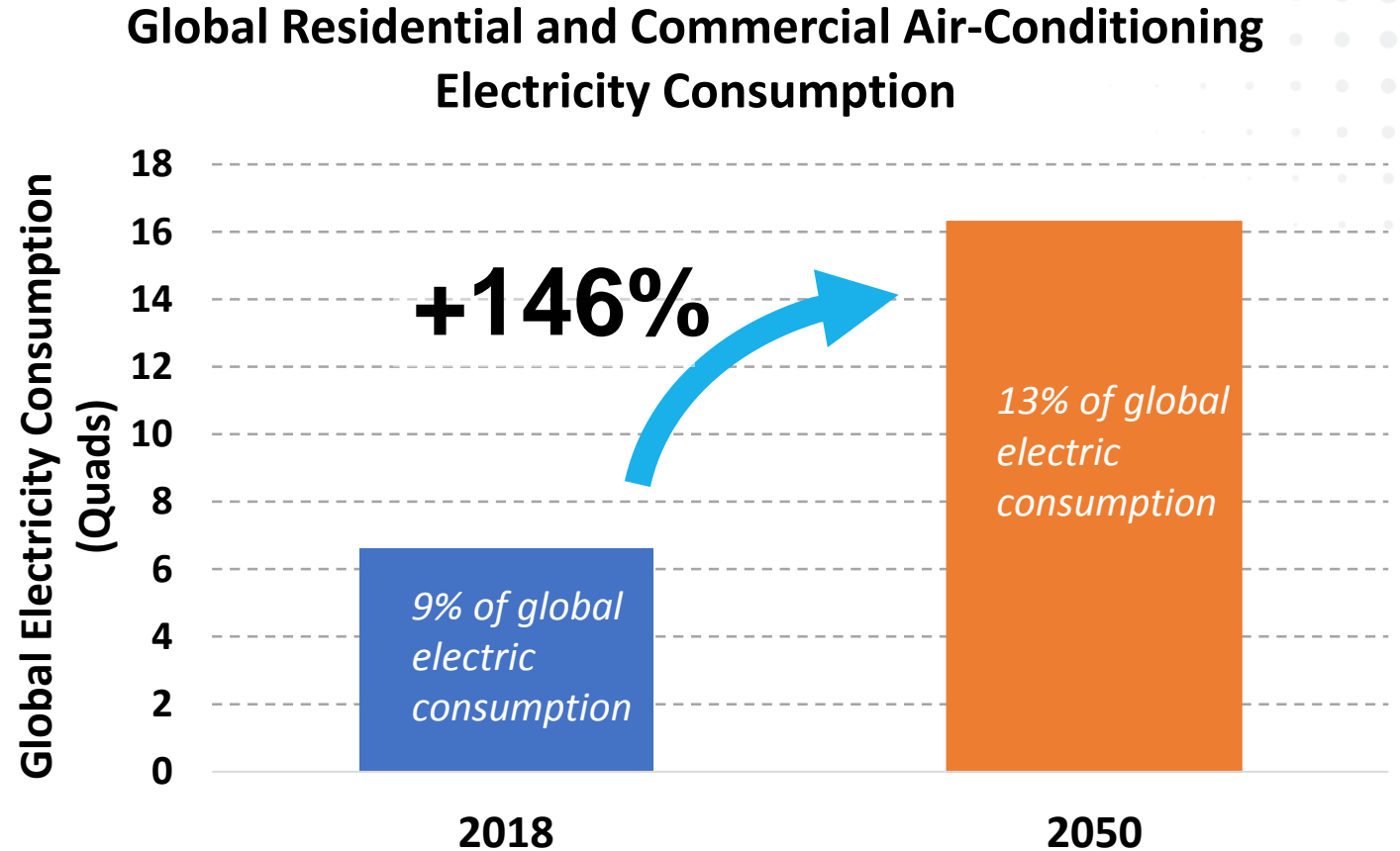
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July 10, 2019

**Go Process
Intensification**

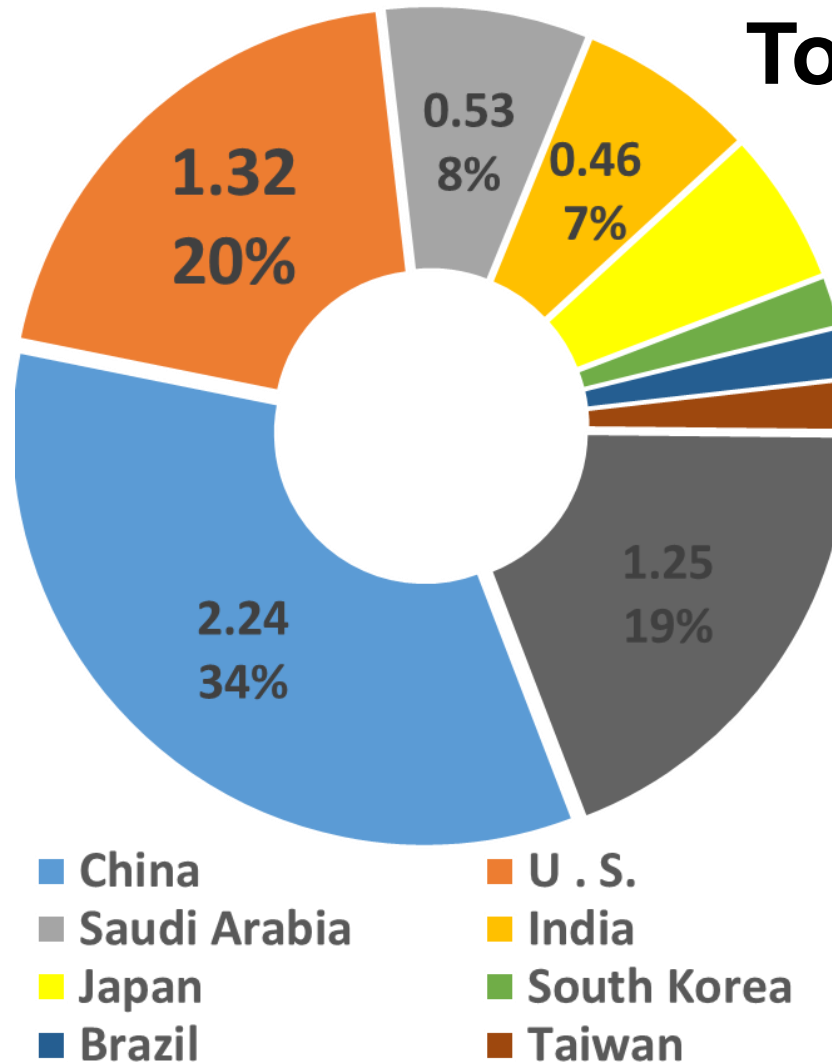
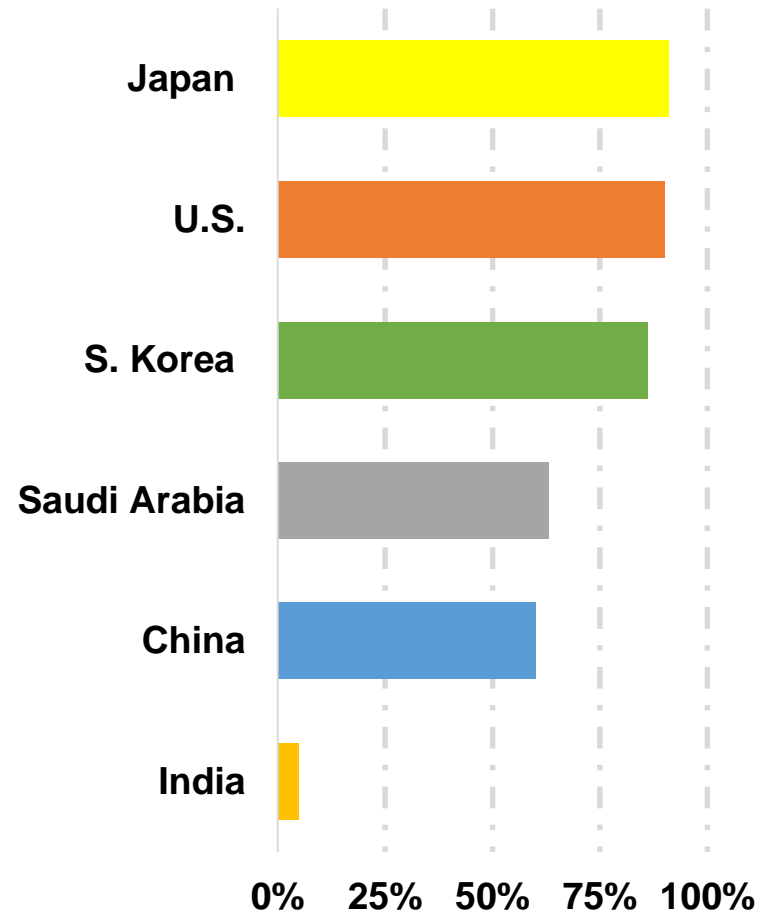
Air Conditioners Consume a LOT of Energy!

- ▶ **Consumes 6.6 Quads** of electricity worldwide
- ▶ Demand to reach **16.3 Quads in 2050**
- ▶ Increased global ownership affects load profiles and demand



Today's Global Electricity Demand for Air Conditioning

Share of Ownership

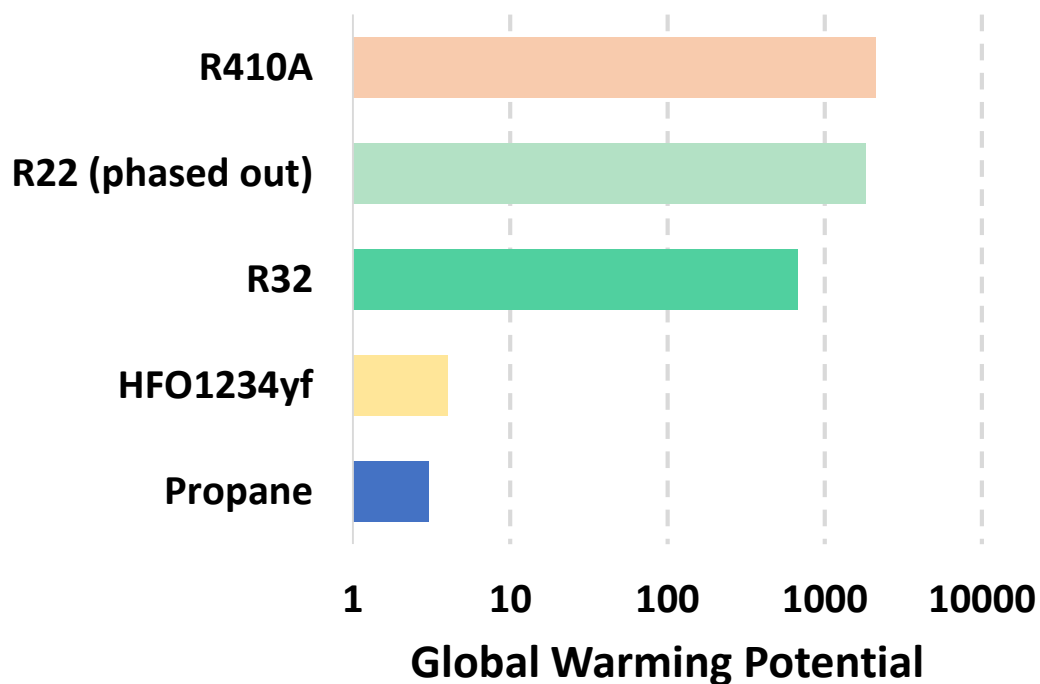


Total: 6.6 Quads (2018)

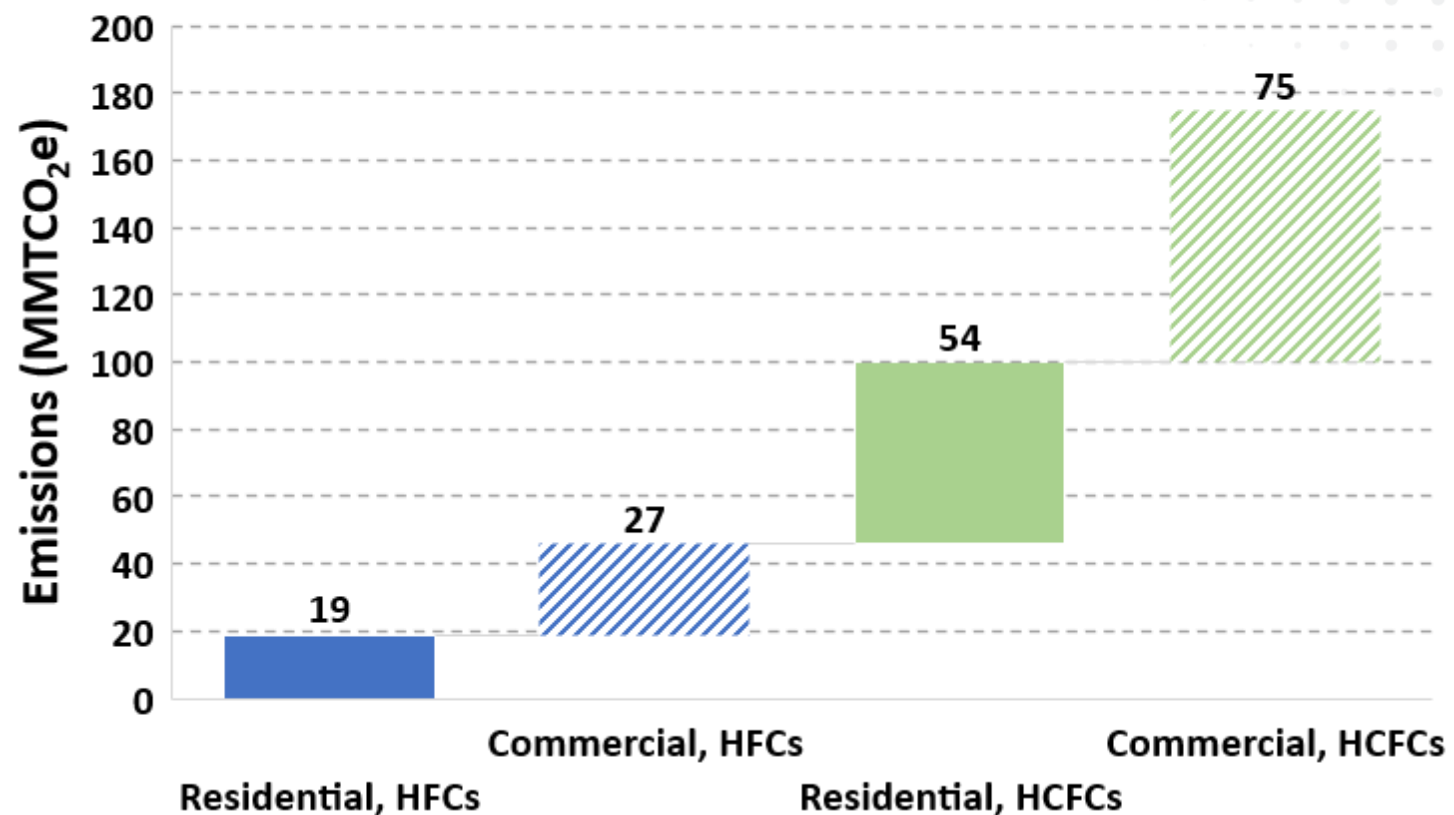
More than 100 million-units sold per year (globally)

Refrigerants Are Not Benign

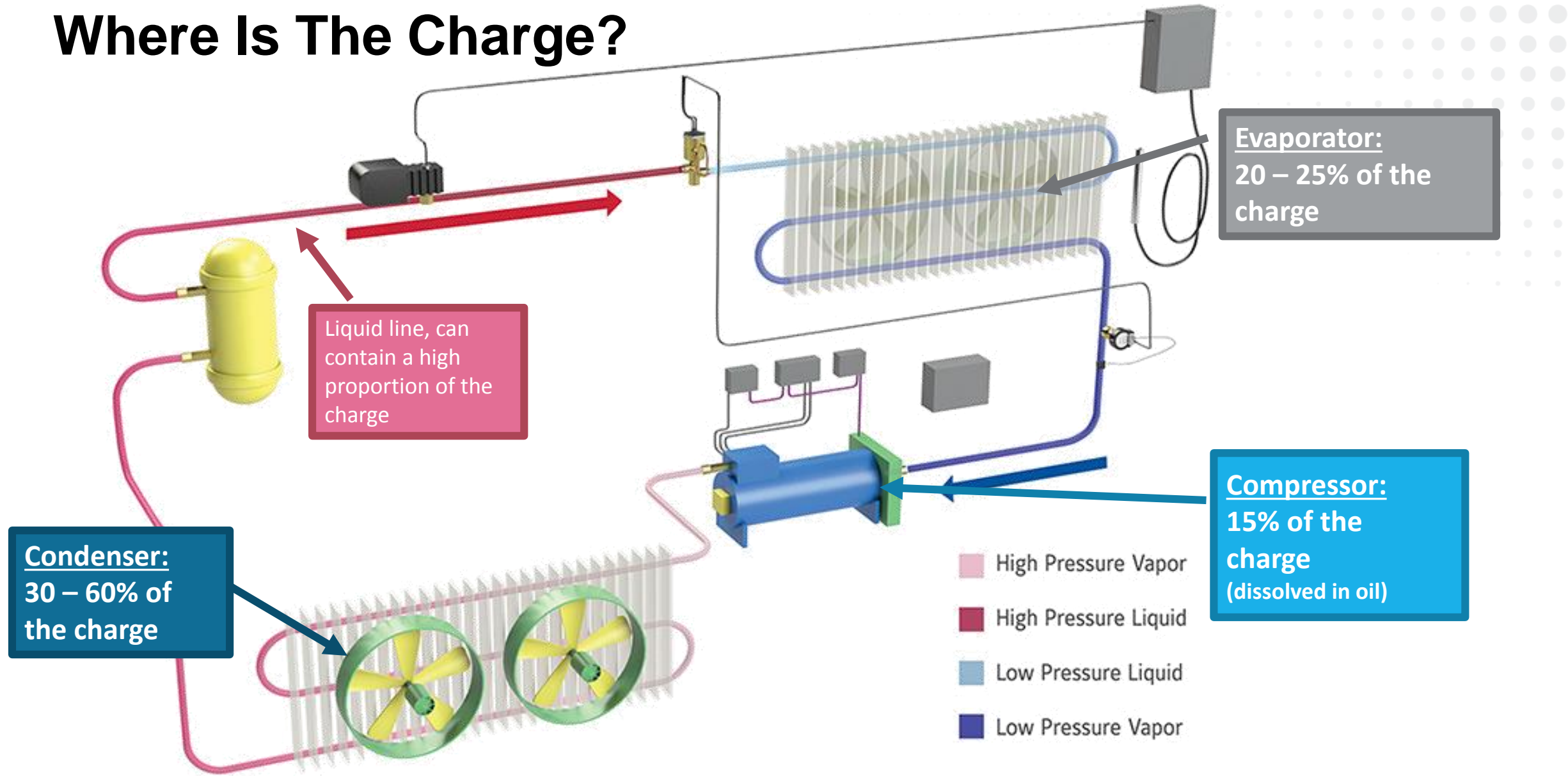
GWP of few common refrigerants
(Ref. CO₂ = 1)



Estimated Global Direct GHG Emissions from
Air Conditioning Systems (2010)



Where Is The Charge?



The Opportunity & The ARPA-E Hard Challenges

Substantially reduce the refrigerant charge requirement

Substantially shrink the system weight/volume

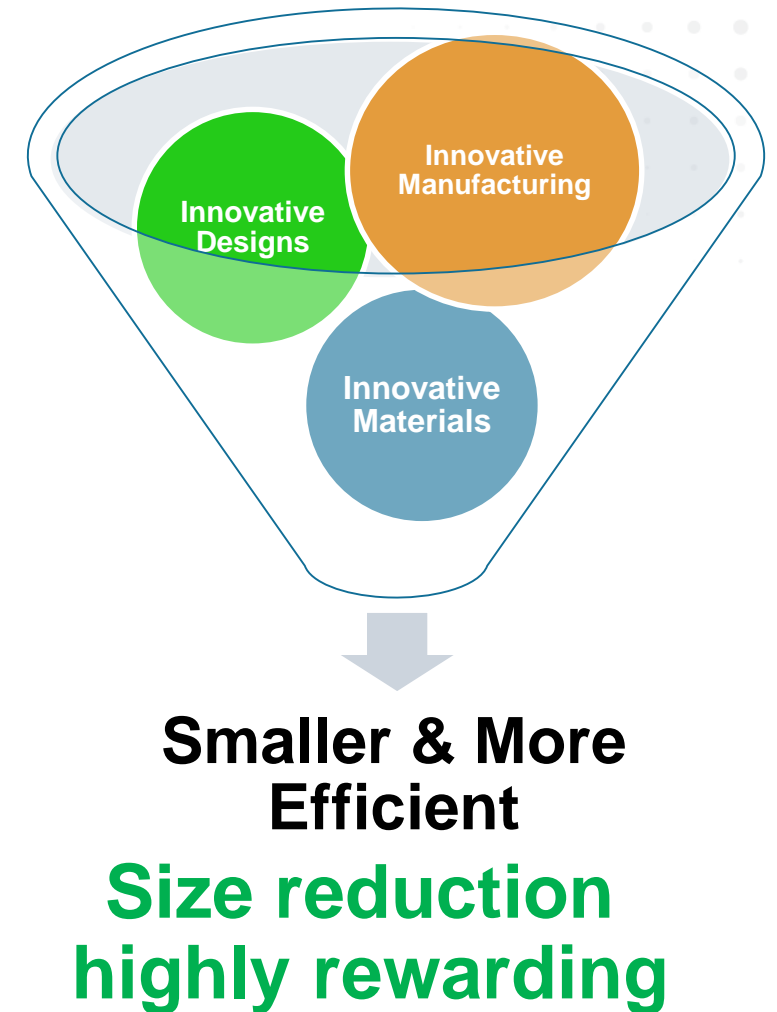
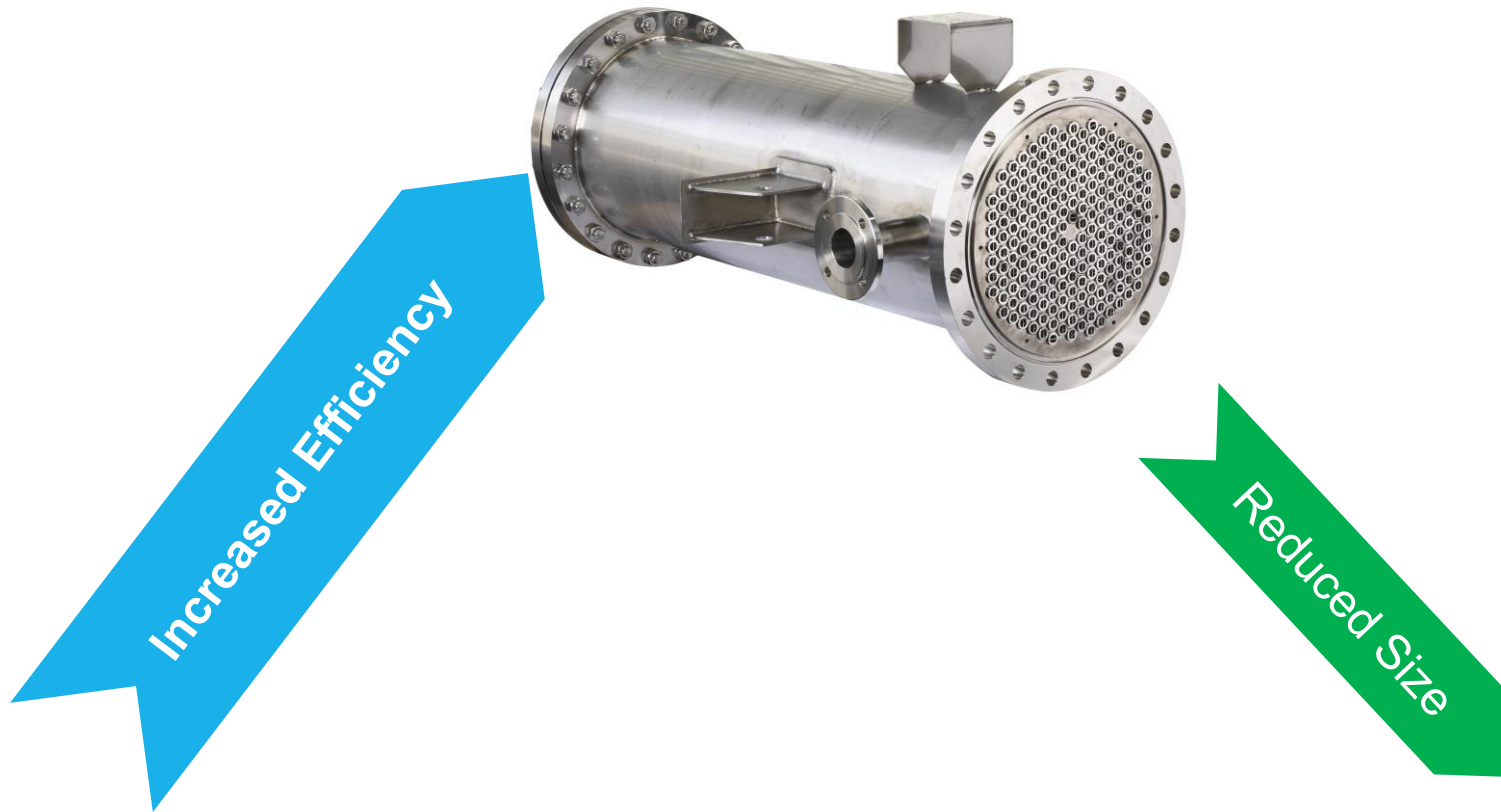
Increase the COP (energy efficiency)

Reduce system capital and operational cost

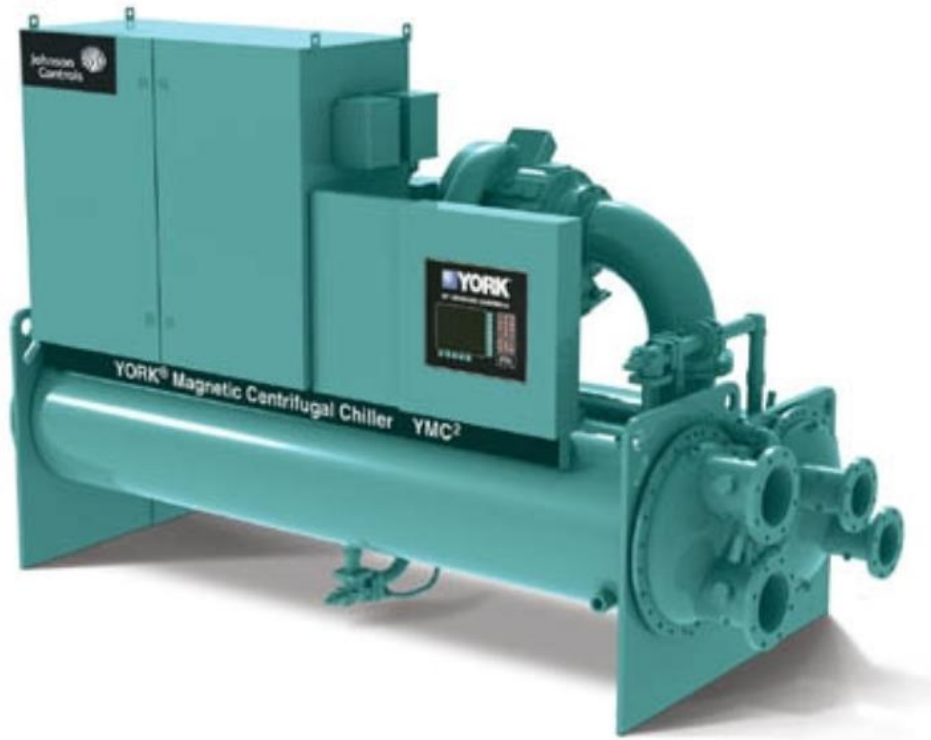
Enable prognostic health management and operational optimization

The Philosophy: Process Intensification

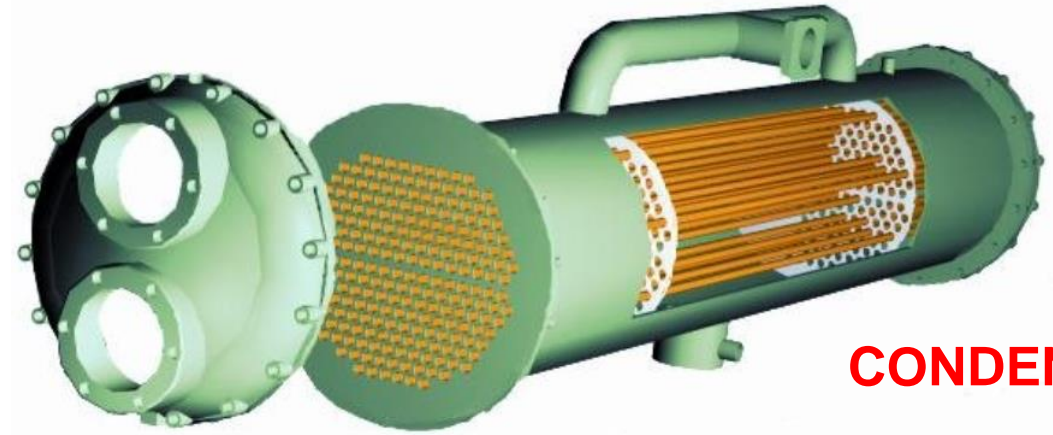
**New eco-friendly refrigerants are
> 10X more expensive**



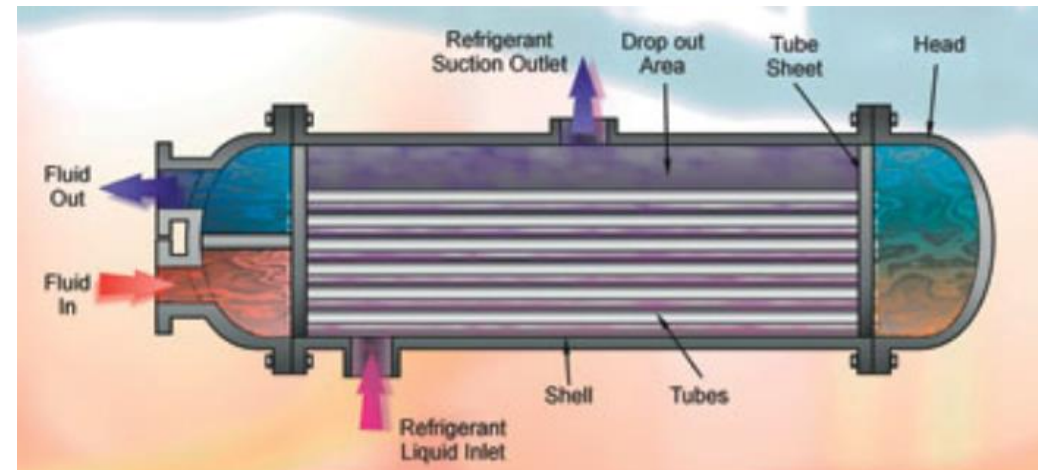
State of the Art Heat Exchangers For Chillers



WATER COOLED CHILLER

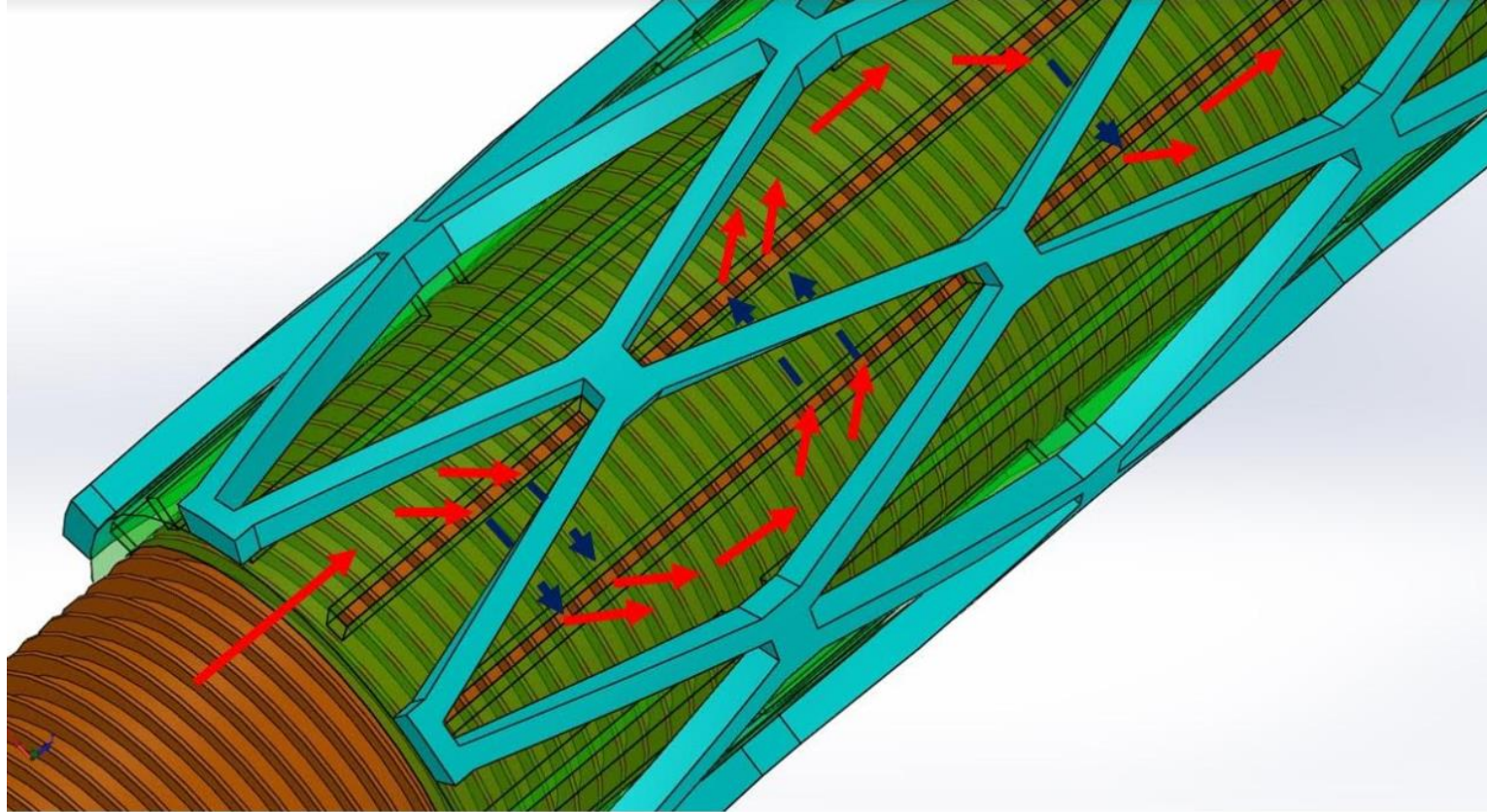


CONDENSER



EVAPORATOR

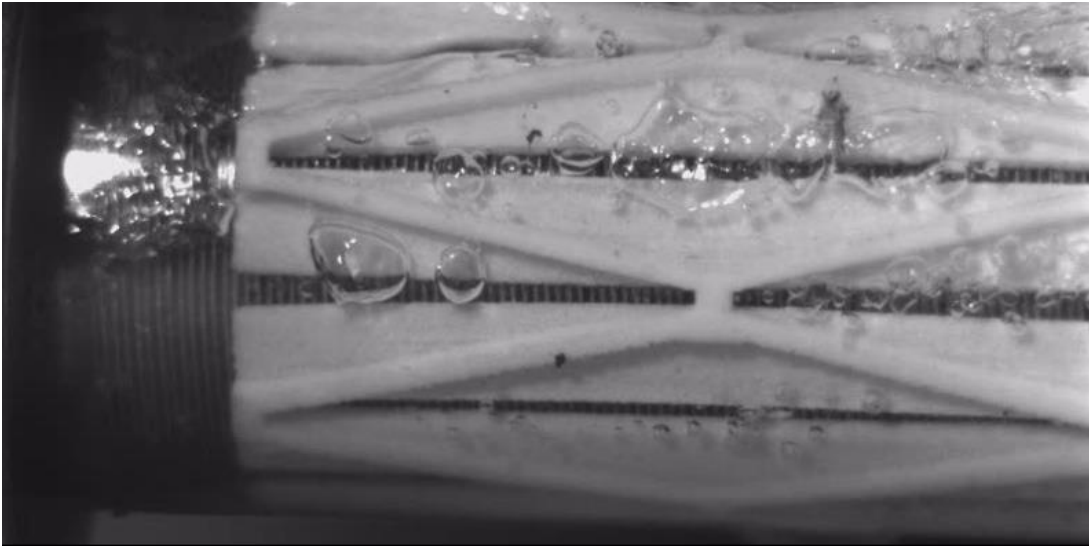
Case Example on Refrigerant Charge Reduction



Refrigerant is fed on the surface of the tube.
Jacket designed to **intensify the evaporation process**

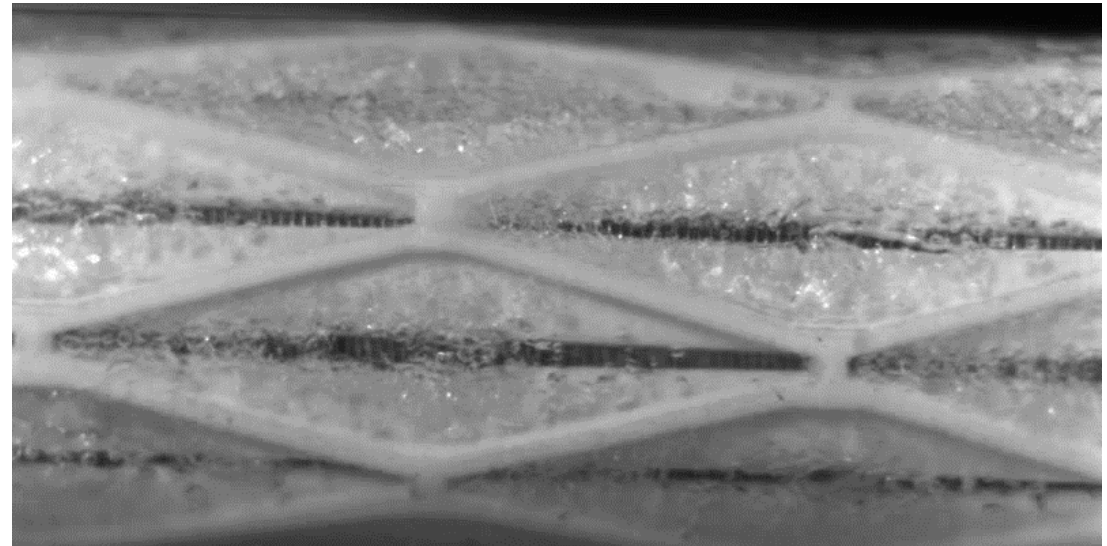
Nucleation/Evaporation Intensification

Inlet

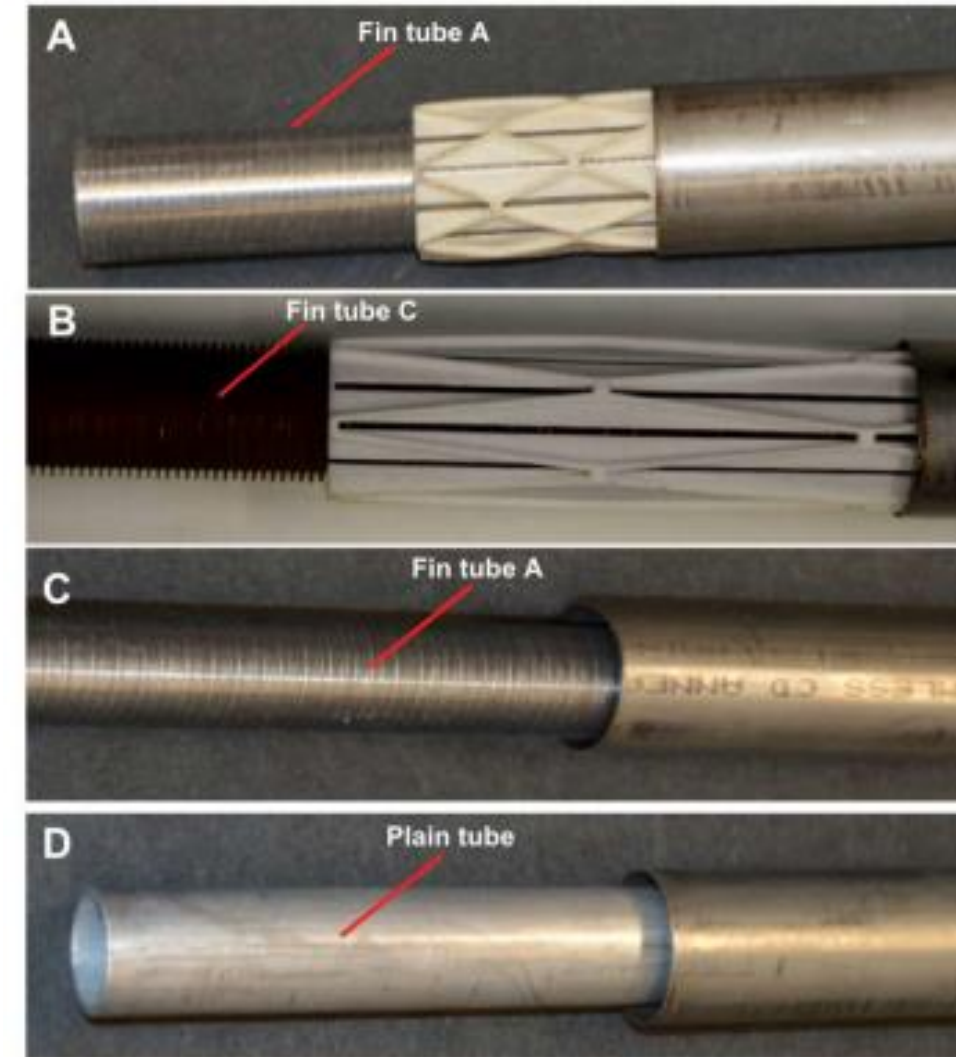
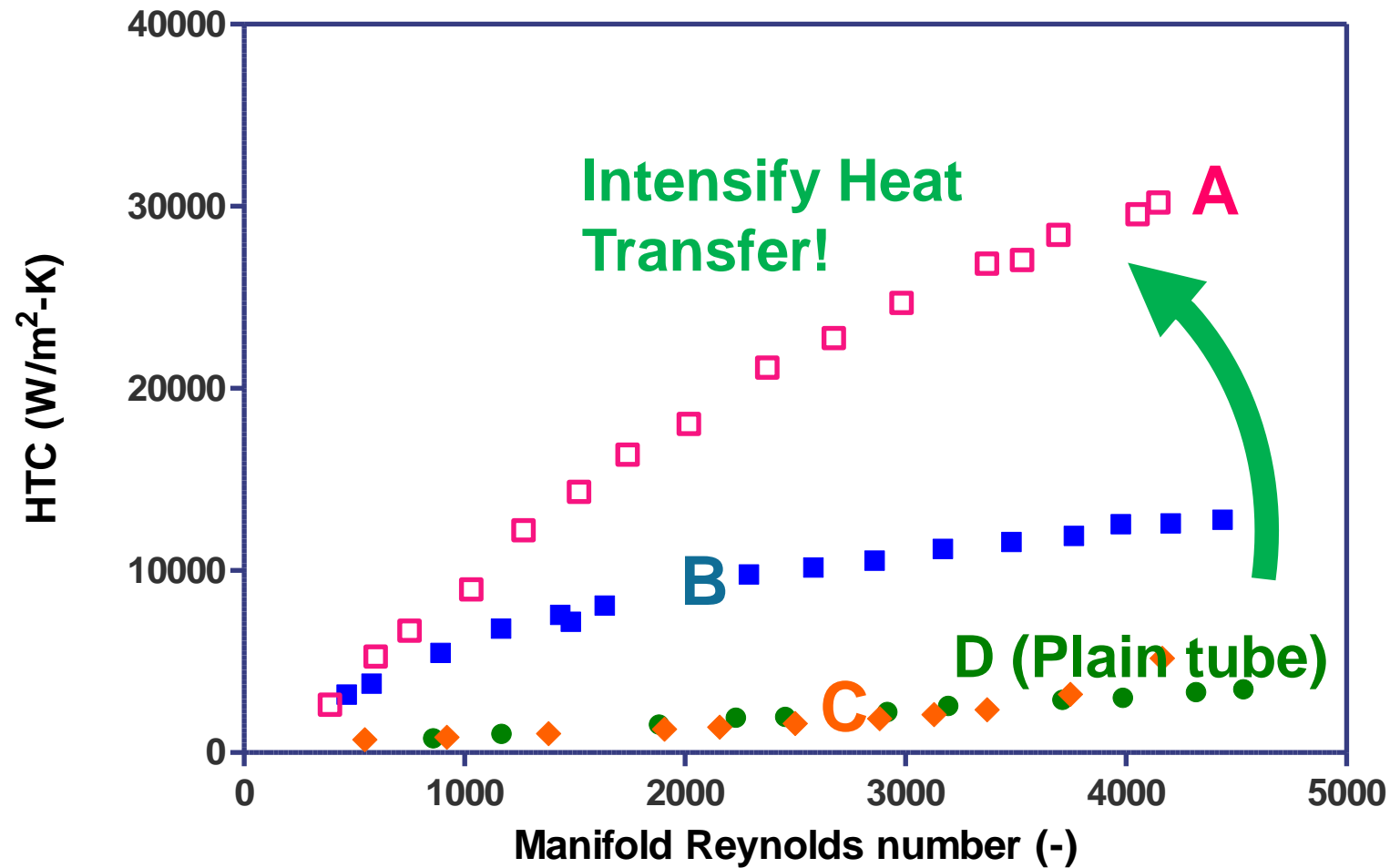


liquid flow 4 kg/min and gas flow 6 liters/minute

**After 4
passes**

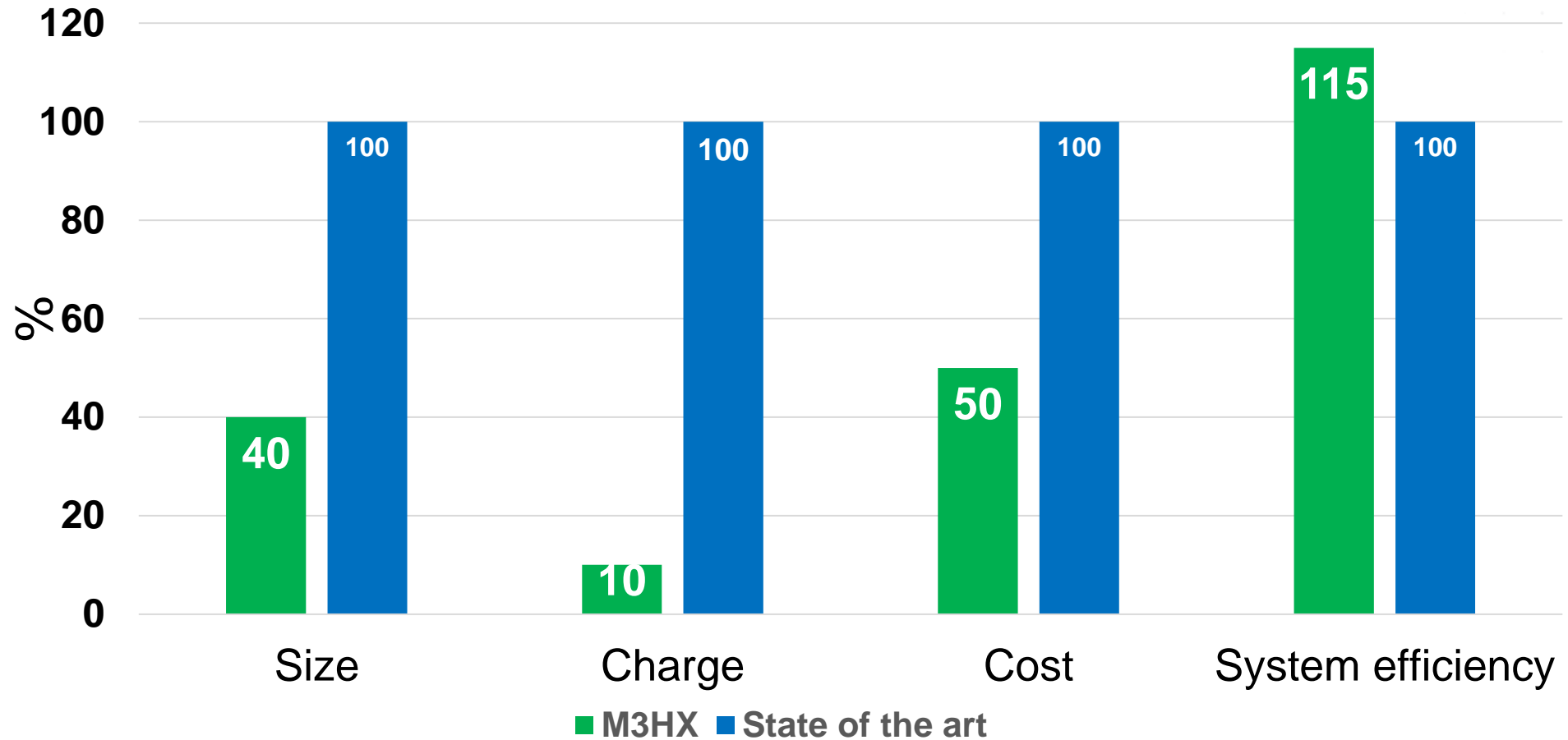


Convective Heat Transfer (Single Phase)



M3HX vs State of the Art:

Lower Refrigerant Charge for Higher Heat Transfer & Efficiency



*All values are relative
(i.e. highest number is given a value of 100)

Category 1:

Transformation improvements
in existing systems

Category II:

New transformative approaches
to achieve human comfort and
optimum built environment



Your thoughts?

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